Approximate 2D-3D Shape Matching for Interactive Applications

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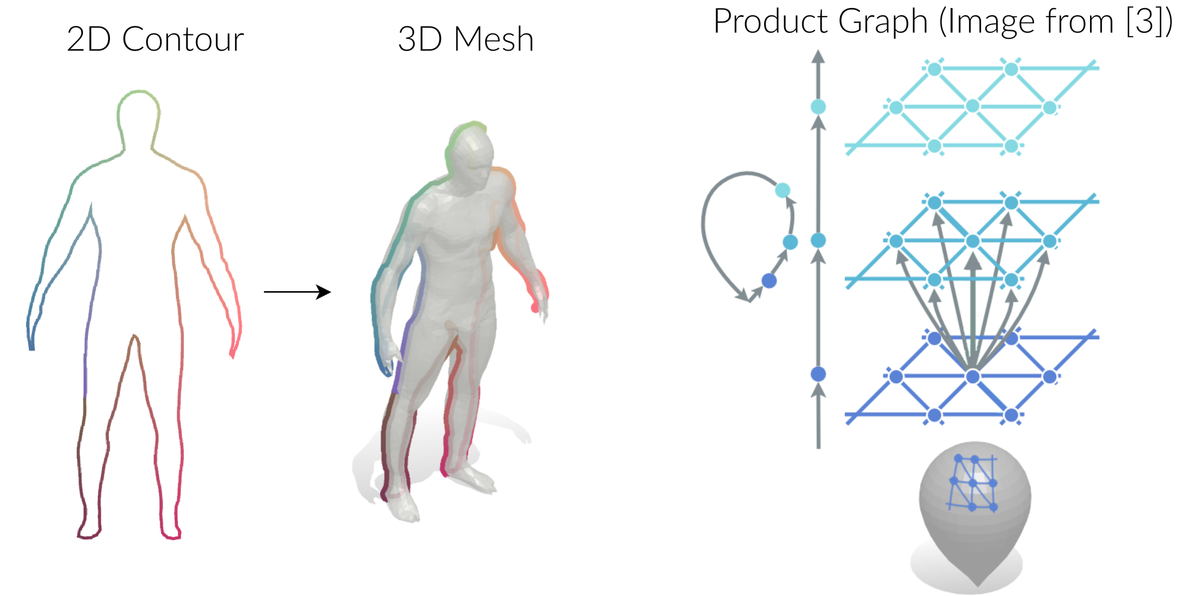
2D-3D Shape Matching

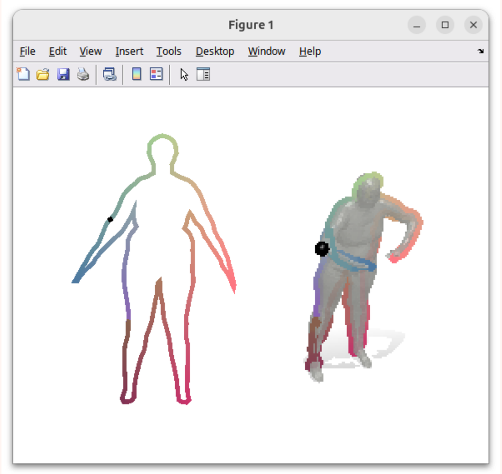
- **Goal:** Obtain high-quality correspondences between 2D contour and 3D mesh efficiently
- **Approach:** Find shortest cyclic path in product graph



- **Applications:** 3D shape retrieval querying with 2D contours, 2D-to-3D deformation transfer, 2D-to-3D segmentation transfer, ...

Our Contributions

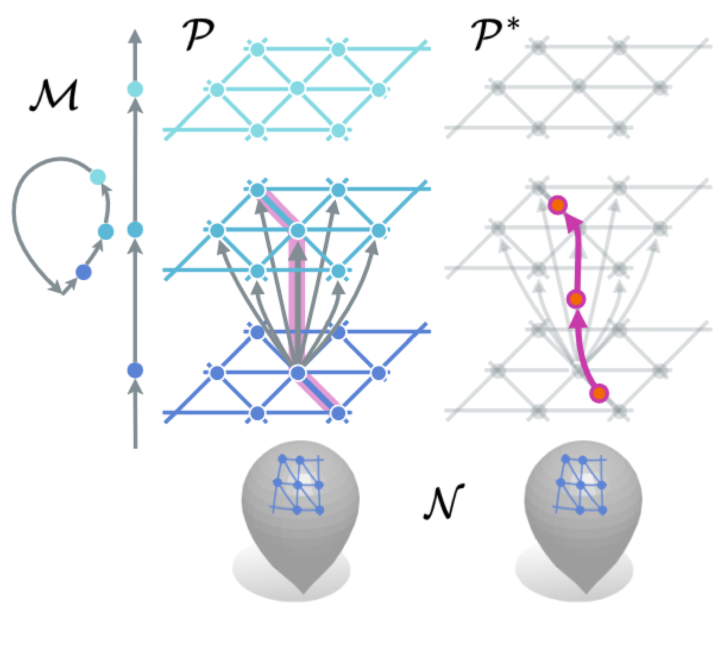
- **Fast** computation of **high-quality** solutions through approximated shortest paths*
- Approximated path costs are (empirically) at most 10% higher than global optimum in all experiments
- Our method enables high-quality interactive landmark matching (see GUI on the right)



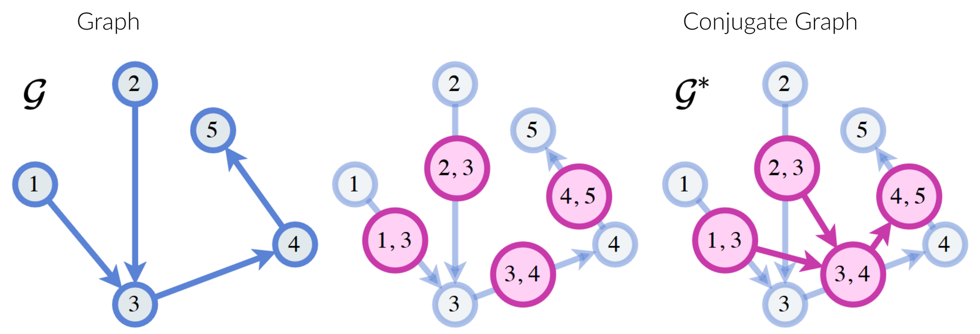
Related Works

- Lähner *et al.* [1] use the product graph and only first order costs ⇒ **fast** but **low-quality** (since deformation between edges is not penalised)
- Roetzer *et al.* [3] use the conjugate product graph and higher order costs (penalising deformation between edges) ⇒ **high-quality** (but **slow** due to larger graph size)

Conjugate Product Graph (Image from [3])



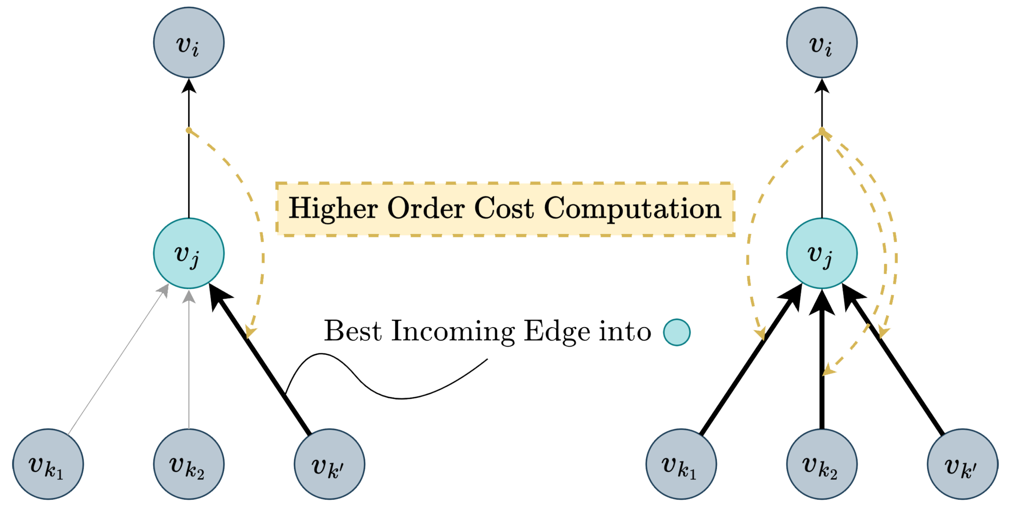
Conjugate Graph Computation (Image from [3])



Our Approximation Method

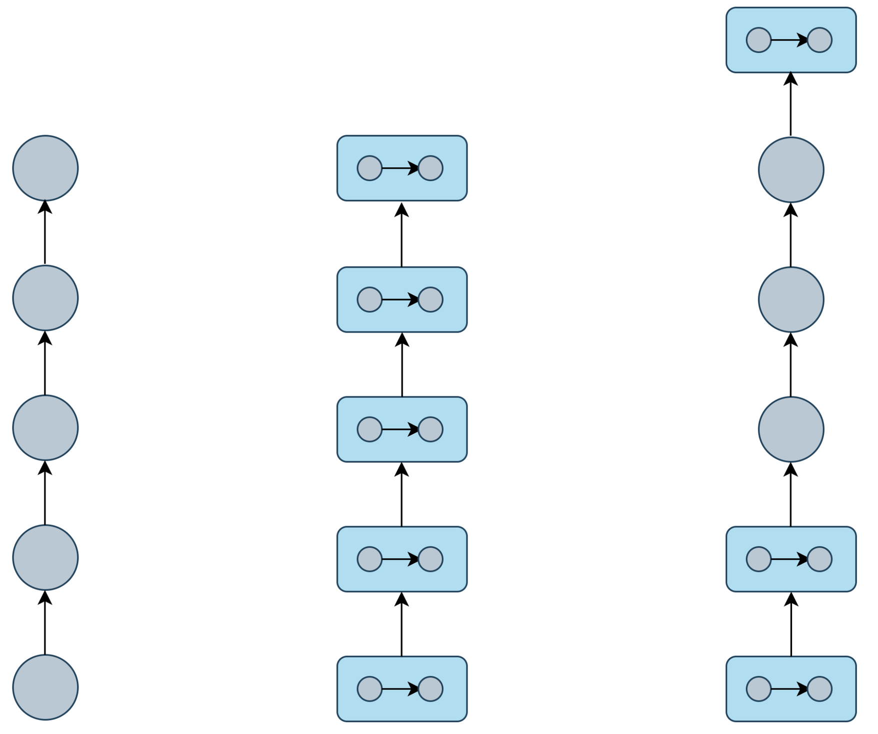
Key Idea: Use product graph instead of conjugate product graph and approximate higher-order costs by considering best incoming edge into a vertex:

- Best incoming edge is known via dynamic programming
- Best incoming edge and subsequent edge are used to computed higher-order costs
- Not all pairs of edges are considered (see yellow lines on the right) ⇒ approximation



Comparison of Graph Structures

- Lähner *et al.* [1]: incoming edge is irrelevant ⇒ product graph
- Roetzer *et al.* [3]: all incoming edges are considered ⇒ conjugate product graph
- Approximation method: only best incoming edge is considered ⇒ product graph
- Ours: best incoming edge is not known on first layer ⇒**blended** product graph



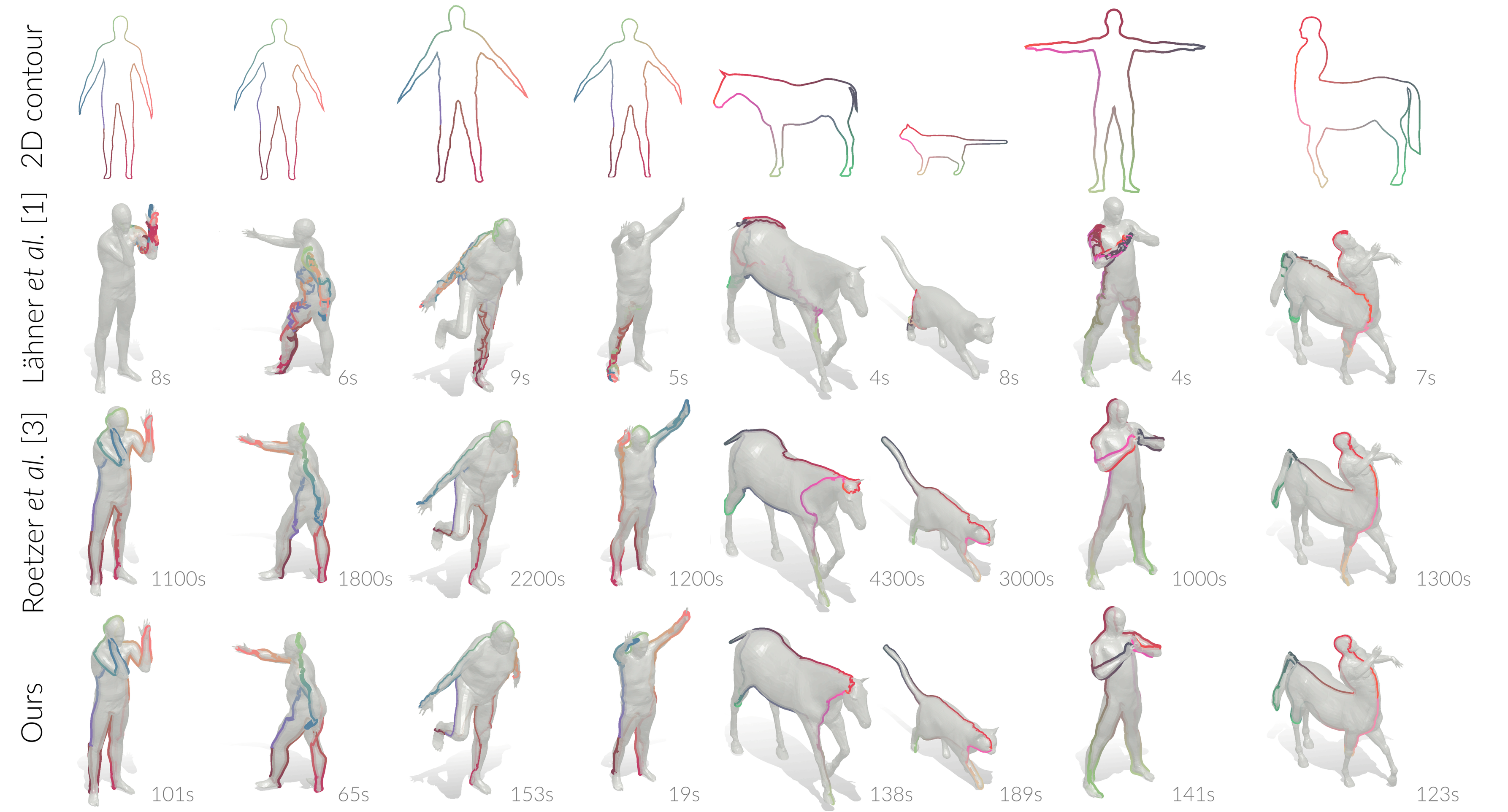
Time Complexity

	Lähner *et al.* [1]	Roetzer *et al.* [3]	Ours
Higher-Order Costs	✗	✓	✓
Worst-case complexity	$mn^2 \ln(n)$	$169mn^2 \ln(n)$	$13mn^2 \ln(n)$

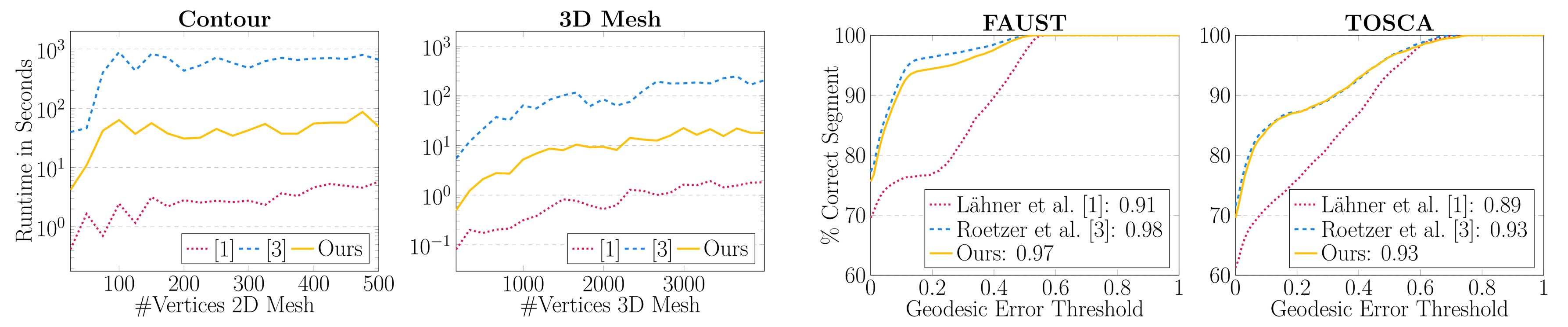
⇒ Ours has approximately 13× lower worst-case runtime than Roetzer *et al.* [3] while also considering higher-order costs

Results

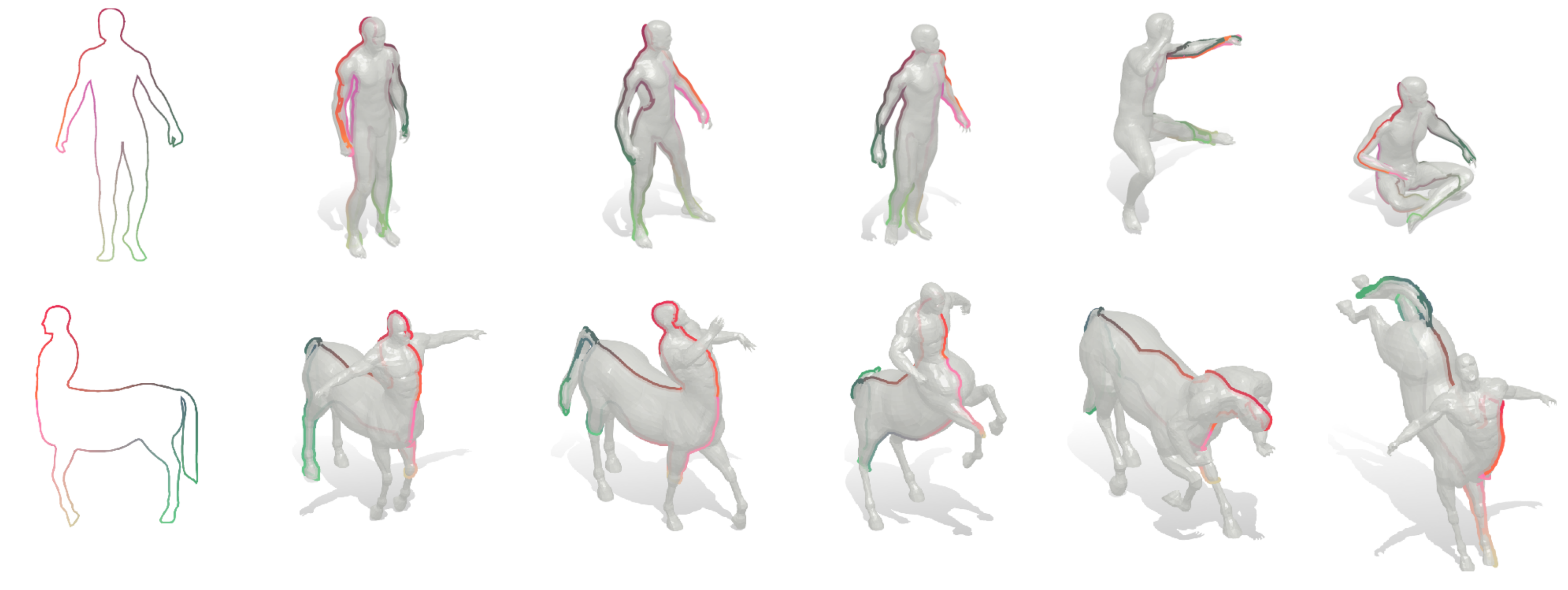
Qualitative Results



Quantitative Results



Application: 3D Shape Retrieval using 2D Query



References

[1] Zorah Lähner, Emanuele Rodola, Frank R Schmidt, Michael M Bronstein, and Daniel Cremers. Efficient globally optimal 2d-to-3d deformable shape matching. In *CVPR*, 2016.

[2] Paul Roetzer, Viktoria Ehm, Daniel Cremers, , Zorah Lähner, and Florian Bernard. Higher-order ratio cycles for fast and globally optimal shape matching. In *CVPR*, 2025.

[3] Paul Roetzer, Zorah Lähner, and Florian Bernard. Conjugate product graphs for globally optimal 2d-3d shape matching. In *CVPR*, 2023.

*In a follow-up work we showed that using higher-order ratio cycles can further decrease runtime without requiring any approximation [2] .